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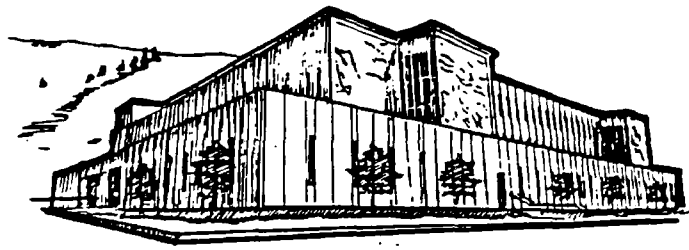
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**STIMULUS EFFECTS ON LOUDNESS
DISCOMFORT LEVELS AND SELECTING
A HEARING AID FITTING MATRIX**

By

Lisa Judge

B.A., University of Montana, 1988

Presented in partial fulfillment of the requirements


for the degree of

Master of Communication Sciences and Disorders

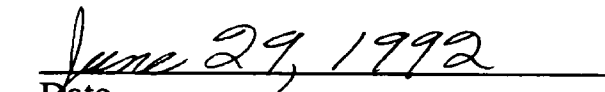
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Chapter I: Introduction

Several measurements obtained during hearing aid evaluations assist audiologists in their selection of appropriate amplification systems for hearing-impaired individuals. Loudness Discomfort Level (LDL) is one of these important measurements. The primary purpose for obtaining LDL is to provide information necessary to set the saturation sound pressure level (SSPL90) or maximum power output (MPO) of a hearing aid. Specifically, the audiologist attempts to determine the output level that will not exceed the user's level of discomfort (Beattie & Boyd, 1986; Hawkins, 1980). When the maximum output of a hearing aid is allowed to exceed the user's level of discomfort, the user tends either to reject the hearing aid or to reduce the overall gain of the hearing aid in an attempt to prevent sudden environmental sounds from causing discomfort (Hawkins, 1980). If the overall gain is lowered, the hearing aid may then provide a less than optimal intensity level for receiving speech and environmental sounds (Hawkins, 1980; Hawkins & Schum, 1991; Hawkins, Walden, Montgomery, & Prosek, 1987; Sammeth, Birman, & Hecox, 1989; Skinner, 1988; Stelmachowicz, Lewis, Seewald, & Hawkins, 1990).

While many audiologists realize the importance of obtaining LDLs during a hearing aid evaluation, there is little agreement on which clinical protocol provides the most valid and reliable measure of the user's level of discomfort. The procedures used to obtain LDLs differ across several dimensions including the presentation of instructions, the stimuli used, the psychophysical methods employed, and the manner in which the chosen stimuli are delivered (Hawkins et al., 1987). The current study

investigated the relationship between three different types of stimuli used to determine LDLs and their application to the selection and fit of hearing aids.

Speech Stimuli and LDLs

Several authors have promoted the use of speech stimuli to obtain LDLs (Dirks & Morgan, 1983; Morgan, Dirks, Bower & Kamm, 1979). Audiologists typically present spondee words or continuous discourse when they use speech stimuli to determine the hearing aid user's LDLs. Spondee words are two syllable words with equal stress on each of the two syllables and include words such as airplane and railroad. Whether presented via monitored live voice or via recorded materials, the use of spondee words has the advantage that the audiologist can monitor the presentation level on the V-U meter of the audiometer. This monitoring ensures that the presentation level remains relatively constant across repeated trials. Spondee words, however, do not represent a true representation of a speech act. Generally speech acts are a series of segmental and suprasegmental elements which form running speech. Continuous discourse can also be presented via monitored live voice or via recorded materials, but this running speech presents unequal frequency and intensity changes across syllable production. As a result, this type of stimulus is neither consistent or reliable across trails or across subjects.

Most clinicians who promote using speech stimuli to obtain LDLs argue that speech allows for a more realistic comparison to the sounds that the hearing aid user will encounter in everyday listening situations. They maintain that frequency specific sounds such as pure tones rarely occur in a hearing aid user's typical listening

environment and, therefore, should not be used for LDL measurement. They also contend that LDLs for speech stimuli can be obtained in less time than LDLs measured at several different frequencies, increasing the efficiency of the test (Beattie & Boyd, 1986). The increase in efficiency can be a critical factor in many clinical settings where time constraints limit the nature and extent of hearing aid evaluations.

Frequency-Specific Stimuli and LDLs

Several other authors have stated their preference to establish LDLs with discrete stimuli such as pure-tones (Berger, 1980; Hawkins et al., 1987; Stelmachowicz et al., 1990) or narrow bands of noise (Cox, 1980, 1983; Shapiro, 1976). These authors purported that frequency-specific stimuli allow for a more accurate measurement of LDLs than speech and thus improve the validity of the SSPL selection, particularly over what can be provided by a broad-band stimulus such as speech. Hawkins (1980; 1987) noted that the use of frequency specific pure-tones is necessary because the SSPL of a hearing aid varies as a function of frequency and bandwidth. He also maintained that LDLs for hearing-impaired persons may differ significantly across frequencies. He reasoned that when speech stimuli are used, the hearing-impaired person may be responding to only a restricted frequency region within this broad-band signal where the intensity of speech is greater. Therefore, a user's response to this selected frequency region can lower the overall LDL for speech and/or environmental sounds. As the SSPL90 or MPO of a hearing aid is lowered to fall within this lowered LDL level, the dynamic range for speech stimuli becomes

inappropriately narrowed and speech intelligibility becomes adversely affected (Beattie & Boyd, 1986).

Dynamic Range

Dynamic range is defined as the range of intensity levels between the listener's threshold and LDL for a specific signal (Skinner, 1988). Skinner has also referred to this range as an individual's auditory area. Somewhere within this auditory area is a range of comfortable loudness levels, which is bounded by lower and upper intensity limits. The most comfortable loudness (MCL) level lies within this range (Skinner, 1988). Audiologists attempt to obtain thresholds, MCLs, and LDLs to specific stimuli during a hearing aid evaluation in order to adjust the frequency response, gain, and SSPL90 of the user's hearing aids. These measures are obtained for each user in order to set the hearing aid appropriately for each individual (Skinner, 1988). While MCLs and thresholds are obtained to help calculate the amount of gain or amplification required from a hearing aid (Ventry & Johnson, 1978), LDLs are obtained to set the SSPL90 or MPO of a hearing aid at a level that will not exceed the hearing impaired individual's level of discomfort. By providing the best match of the gain and output values to the user's thresholds and dynamic range values, the audiologist attempts to maximize the probability of a successful and effective hearing aid fitting. This postulate is maintained regardless of which hearing aid fitting method is used.

Purpose of the Study

Several audiologists, working at the Department of Veterans Affairs Medical Center (VAMC) in Seattle, expressed concerns regarding the validity of the hearing aid fittings, particularly when selecting the output limits based on LDL measures using speech stimuli. As speech stimuli is dominated by low frequency energy and the majority of the hearing aid users being fit by the Seattle VAMC are patients who have normal or near-normal hearing in the low frequencies, then the LDLs obtained for unshaped speech stimuli are dominated by the frequency regions with near-normal hearing. As a consequence, when this measurement is used to set the SSPL90 or MPO limits of a hearing aid, the hearing aid user may receive speech and environmental sounds at less than optimal levels. In addition, the LDLs may not provide sufficient information regarding how the output limits of the hearing aid should be set for individuals using hearing aids which amplify high frequency stimuli. Since these hearing aids tend to have their peak gain at 2000 Hz, low frequency measurement of dynamic range values may be inappropriate.

The purpose of the current study was to establish the relationship between LDLs obtained with three different types of stimuli and to determine whether these LDLs resulted in any changes in a hearing aid matrix when they were incorporated into a hearing aid selection strategy for SSPL90. If stimulus characteristics do indeed influence LDL measurements, then these differences will be reflected in the SSPL90 values chosen for a hearing aid matrix. This study investigated the use of the following stimuli to measure LDL:

- 1) CID W-1 spondee words (broadband stimuli) presented monitored live voice,
- 2) 500, 1000, and 2000 Hz pure tones (frequency-specific stimuli), and
- 3) two narrowband noises centered at 500 and 2000 Hz (band-restricted stimuli).

Finally, the LDL data were directly applied in the selection of SSPL90 values for hearing aid circuits to determine if differences existed among the circuits when different stimuli were used to measure LDLs.

Chapter II: Methods

Subjects

A total of 10 subjects participated in this study. Due to the monaural hearing aid fitting policy within the Veterans Administration, the results were limited to the data obtained from the right ear of each subject. The ages of the subjects ranged from 50-75 years. The subjects exhibited audiograms with no better than a 20 dB HL threshold at 1000 Hz and no greater than a 35 dB slope between 1000 Hz and 2000 Hz. Mean pure-tone and speech audiometric data from the subjects are summarized in Table 1.

Table 1. Means and standard deviations for pure-tone and speech recognition thresholds

Ear	Pure Tone Thresholds in dB HL								SRT in dB HL	
	500 Hz		1000 Hz		2000 Hz		4000 Hz		R	L
	R	L	R	L	R	L	R	L		
Mean	20.5	19.5	34.5	35.0	51.0	49.5	76.0	76.5	31.5	33.0
S.D.	8.5	6.1	13.5	10.0	16.1	13.9	17.6	17.6	6.7	9.6
Range	5-35	10-30	20-55	20-50	20-80	25-65	50-110	45-110	20-45	20-45

Stimuli and Instrumentation

Pure-tones and band-restricted noise stimuli were generated by a Grason-Stadler Model 10 two-channel diagnostic audiometer and directed to TDH-50 earphones encased in MX-41/AR cushions. The pure-tone stimuli were limited to three frequencies (500, 1000, and 2000 Hz) and were pulsed (400 ms on, 400 ms off).

Higher frequencies were not chosen for testing in this study so that LDLs obtained to specific frequencies within the conventional speech spectrum (500 - 2000 Hz) could be compared to the LDLs obtained to speech stimuli. The speech stimuli used in this study consisted of spondee words from the CID W-1 word list presented via monitored live voice. The band restricted noise was limited to stimuli centered at two frequencies (500 and 2000 Hz) and were also pulsed for comparative purposes. The audiometer was calibrated to the specifications described in ANSI S3.6-1989. All testing occurred in a double-walled sound suite meeting the noise criteria for threshold testing specified in ANSI S3.1-1977.

Procedures

The subjects were instructed that they would be listening to groups of words, tones, and noise at various levels. Each subject was asked to make loudness judgements regarding these three types of signals. The Most Comfortable Listening level (MCL) measurement was obtained first which was followed by the measurement of the Loudness Discomfort Level (LDL). Each subject was instructed about the nature of the task and how they should respond to the stimulus presentation prior to the administration of each protocol. These instructions are presented in Appendix A. The subjects were then asked to make their selections of loudness judgement from a closed-set choice list developed by Hawkins et al. (1987). This list is presented in Appendix B.

As several studies have recommended using an ascending approach to obtain LDLs (Hawkins, 1980; Hawkins, et al., 1987; Skinner, 1988), the current study

adopted an ascending approach. The procedure used for obtaining MCLs and LDLs in this study was derived from the protocols described by Sammeth and her colleagues in 1989. To obtain the MCLs, the initial presentation level was 20 dB above SRT and increased in 5 dB steps until the subject judged the level to be "comfortable". Since there is a range of comfortable loudness (Dirks & Kamm, 1976; Ventry & Johnson, 1978), the presentation level was increased until the subject judged the stimuli to be "comfortable but slightly loud." Once the top of the response range was reached, the level was dropped 10 dB and subsequently raised in 2.5 dB steps. MCL was defined as the step below the level at which two responses of "comfortable, but slightly loud" were given. Two presentations of the spondee words, pure-tone stimuli, or band restricted noise stimuli were given at each level, and ascending runs were used to obtain responses.

After obtaining the MCL measurements for the three different stimuli, the LDLs were measured. The loudness judgments were once again derived from the loudness chart in Appendix B. The procedure was identical to that used to obtain MCLs (Sammeth, et al., 1989) except that the first ascending run began at MCL. The subject's LDL was defined as the step below the level at which two responses of "extremely uncomfortable" were given.

For both MCL and LDL measurements, the subject responses were accepted at the top of their response range. These measurements were intended to extend the dynamic range as wide as possible, thus providing a greater area in which to amplify. While this protocol presents some risk of exceeding the listener's MCL and LDL, it

reduces the risk of providing insufficient gain in the hearing aid fitting and narrowing the range of audible sounds in the hearing aid user's environment. The order of presentation was counterbalanced across all stimuli.

Hearing Aid Fitting Protocols

When ordering a hearing aid for an individual, audiologists typically examine manufacturers' hearing aid matrices to select the most appropriate circuit for that individual's hearing loss. While each hearing aid manufacturer has their own set of matrices for hearing aid fitting, all manufacturers typically specify the following measurements within their matrix options: 1) peak output or SSPL90, 2) peak gain, and 3) frequency response or slope. The matrix that best fits a individual's prescription based on one or more fitting models is then chosen as the most appropriate circuit for that individual's hearing aid.

For this study, the same prescriptive model was used across all subjects to determine if the LDLs obtained with the different types of stimuli would results in the selection of different hearing aid circuits for a particular subject, the data obtained above were entered into a modified National Acoustics Laboratory--Revised (NAL-R) hearing aid prescriptive strategy developed at the Seattle VAMC. The modifications to NAL-R are described in Appendix C. Using a BASIC programming language, this prescriptive strategy was programmed and compiled into an executable file readily available in the clinic through the use of IBM-PC compatible microcomputers. After obtaining the behavioral data for each subjects, the pure tone thresholds and the speech LDL measurements were entered into this program. The program extracted

Table 2. The computer program's output for subject six's hearing aid fitting matrix.

Input		Estimated and Measured Gain Values		
Frequency in Hz	Threshold (dB HL)	2-cc Gain	Estimated REIG	Obtained REIG
250 Hz	10	1	-12	N/A
500 Hz	10	11	-1	N/A
1000 Hz	20	21	9	N/A
1500 Hz	35	24	14	N/A
2000 Hz	55	30	20	N/A
3000 Hz	90	37	26	N/A
4000 Hz	105	40	29	N/A
6000 Hz	100	29	27	N/A

2-cc Gain at 2000 Hz: 30
Peak 2-cc Gain: 40 at 4000 Hz

Additional Measures	
HF _{AVE} SSPL90: 100 dB SPL	
SLOPE .5 to 2 kHz: 19 dB	

the estimated 2-cc coupler gain at 2000 Hz and the SSPL90 values for speech. Table 2 presents an example of the output of the computer program using this procedure for the data obtained from subject six. For this particular subject, the 2-cc coupler gain at 2000 Hz was 30 dB and the resultant SSPL90 value for speech was 100 dB.

Once the computer generated the 2-cc coupler gain at 2000 Hz and the SSPL90 value for speech, the examiner applied a fitting matrix similar to the fitting matrices developed by several hearing aid manufacturers. This fitting matrix specifically utilized the estimated SSPL90 and peak gain for the speech stimulus and for the 2000 Hz pure tone. These two stimuli were selected over other stimuli parameters for several reasons. First, the speech stimulus is the preferred stimulus for many audiologists. In addition, many hearing aid companies request only the speech LDL on their order forms. The 2000 Hz pure tone was selected in the fitting matrix as the peak gain values of numerous standard hearing aid circuits occur at or near 2000 Hz. Using the speech and 2000 Hz data in the current hearing aid fitting matrix, the following question was asked: What will be the highest input level before the hearing aid will be driven into saturation and begin to distort the signal?

In order to determine the saturation level, the 2-cc coupler gain at 200 Hz (obtained from the modified NAL-R prescriptive formula) was subtracted from the SSPL90 for the speech, the pure-tone, and the band-restricted stimuli. The resulting differences indicated the decibel level at which the hypothetical hearing aid could be placed into saturation. For clarification, the data from subject six using speech and the 2000 Hz pure-tone data are presented in Table 3. The input saturation level for

Table 3. Estimated input saturation levels.

Measurement	Stimulus	
	Speech	2000 Hz Pure Tone
Estimated SSPL90	100 dB SPL	108 dB SPL
2-cc Coupler Gain at 2000 Hz	30 dB	30 dB
Input Saturation Level	70 dB SPL	78 dB SPL

speech was 70 dB SPL while the input saturation level for the 2000 Hz pure tone stimulus was 78 dB SPL.

Statistical Analysis

A one-way analysis of variance (ANOVA) was used to determine any significant differences between the type of stimulus used to measure the LDL. The coefficient of risk was set at .05.

Chapter III: Results

The MCLs (in dB SPL) obtained for the 10 ears tested in this study as well as the mean MCLs and the standard deviations are presented in Table 4. The LDLs (in dB SPL) obtained for the 10 ears testing in this study as well as the mean LDLs and the standard deviations are presented in Table 5. The variances of the MCL and LDL measurements, across and within subjects, are illustrated in Figures 1 and 2. A one-way analysis of variance (ANOVA) with one repeated measure did not reveal any significant differences ($p < .05$) across stimulus conditions for LDL measurement but did reveal a significant difference ($p < .05$) across the subjects. The summary of the one-way ANOVA is presented in Table 6.

For each subject's hypothetical hearing aid fitting, the estimated input saturation level was determined using the fixed gain and fixed SSPL90 values for speech, pure tone, and band-restricted noise stimuli. Figures 3 through 7 illustrate the relationship between the estimated saturation input levels obtained for speech and one of the pure tone stimuli or one of the band-restricted noise stimuli. The results suggest a relatively close agreement between the estimated input saturation levels for speech and a 500 Hz band-restricted noise as well as for speech and the 2000 Hz band-restricted noise. The data between the estimated input saturation levels using a speech stimulus and the pure-tone stimuli are much more discrepant.

Table 4. Most comfortable loudness data, means, and standard deviations in dB SPL.

Subject Number	Speech	Pure Tones			Narrow-Band Noise	
		500 Hz	1000 Hz	2000 Hz	500 Hz	2000 Hz
1	103.00	86.00	82.50	101.00	98.50	98.50
2	95.50	91.00	95.00	108.50	93.50	108.50
3	75.50	76.00	67.50	78.50	76.00	76.00
4	93.00	103.50	95.00	111.00	98.50	93.50
5	90.50	86.00	82.50	88.50	88.50	83.50
6	70.50	78.50	67.50	83.50	88.50	78.50
7	75.50	78.50	70.00	61.00	78.50	78.50
8	85.50	81.00	72.50	68.50	81.00	71.00
9	85.50	81.00	65.00	71.50	88.50	83.50
10	85.50	88.50	85.00	86.00	101.00	98.50
Mean	86.00	85.00	78.25	85.75	89.25	87.00
Standard Deviation	10.06	9.09	11.30	16.93	8.74	12.09

Table 5. Loudness discomfort level data, means, and standard deviations in dB SPL.

Subject Number	Speech	Pure Tones			Narrow-Band Noise	
		500 Hz	1000 Hz	2000 Hz	500 Hz	2000 Hz
1	123.00	128.50	117.50	128.50	118.50	121.00
2	118.00	118.50	120.00	131.00	118.50	121.00
3	118.00	126.00	117.50	123.50	113.50	103.50
4	123.00	133.50	127.50	126.00	113.50	116.00
5	113.00	123.50	120.00	118.50	113.50	116.00
6	100.50	101.00	100.00	108.50	101.00	108.50
7	90.50	96.00	87.50	86.00	96.00	83.50
8	118.00	108.50	105.00	103.50	113.50	108.50
9	115.50	111.00	110.00	118.50	118.50	121.00
10	113.00	113.50	110.00	108.50	118.50	111.00
Mean	112.75	116.25	111.38	115.85	112.50	111.65
Standard Deviation	8.84	11.90	10.34	12.14	7.45	10.20

Table 6. One-way analysis of variance for determining differences between stimuli during loudness discomfort measurements.

Source	SS	<i>df</i>	MS	F Statistic	<i>p</i> -value
Between Groups	202.53	5	40.51	1.47	0.21
Between Case	5708.27	9	634.25	23.01	>0.01
Error	1240.45	45	27.56		
Total	7151.25	59			

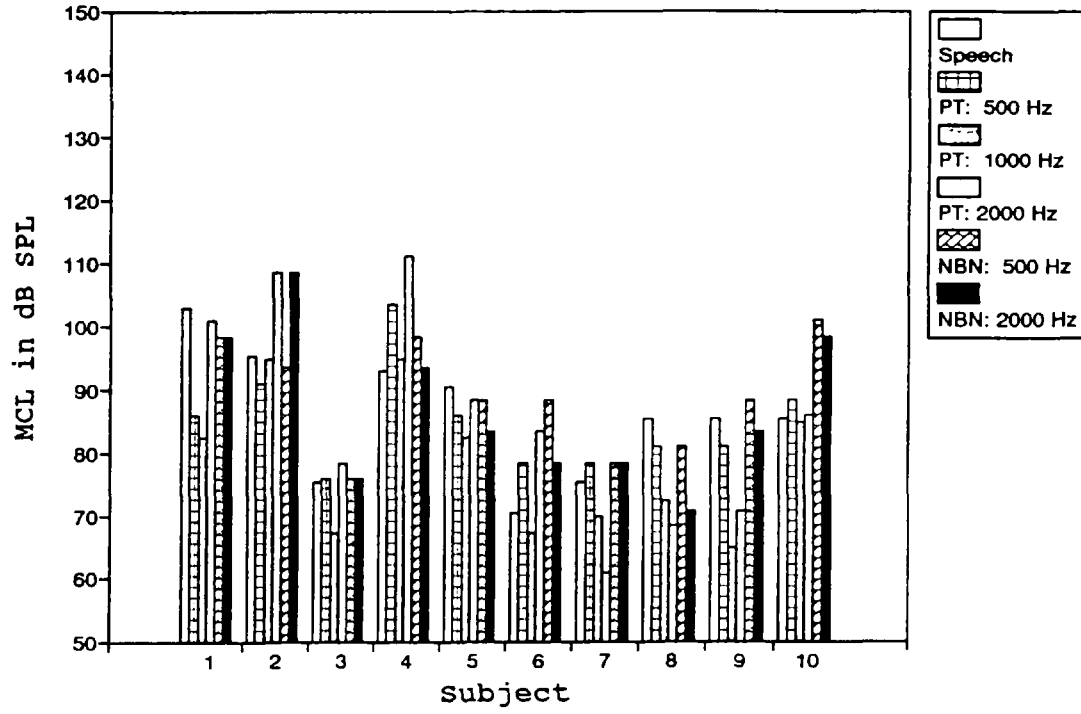


Figure 1. Most comfortable loudness levels in dB SPL across stimulus type.

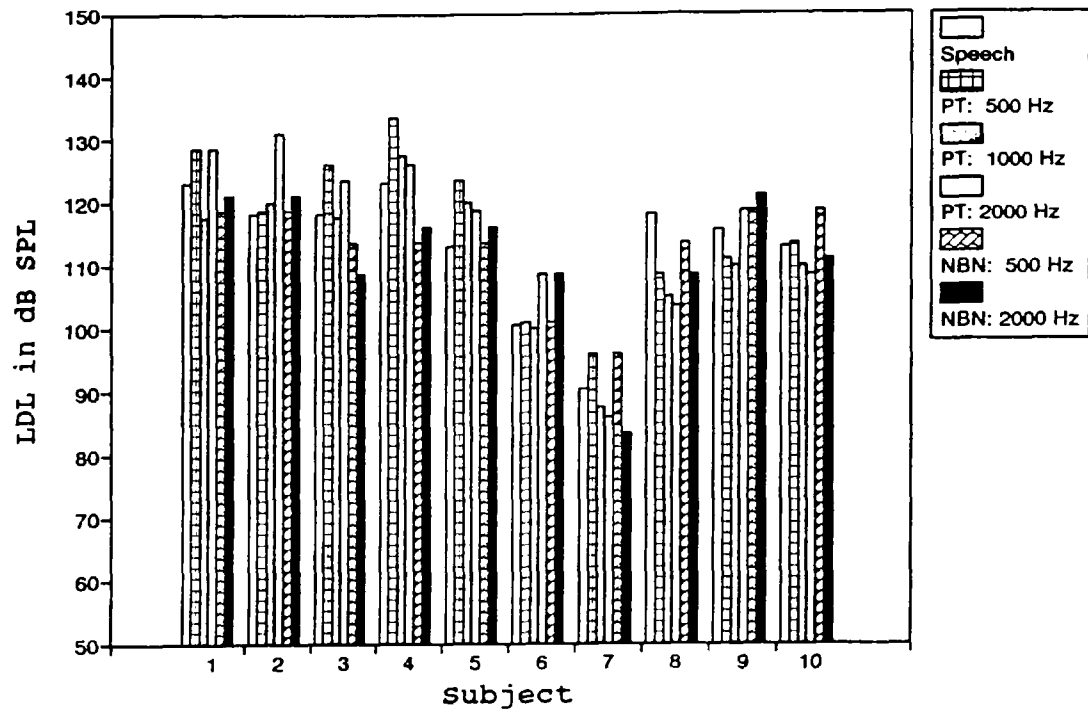


Figure 2. Loudness discomfort levels in dB SPL across stimulus type.

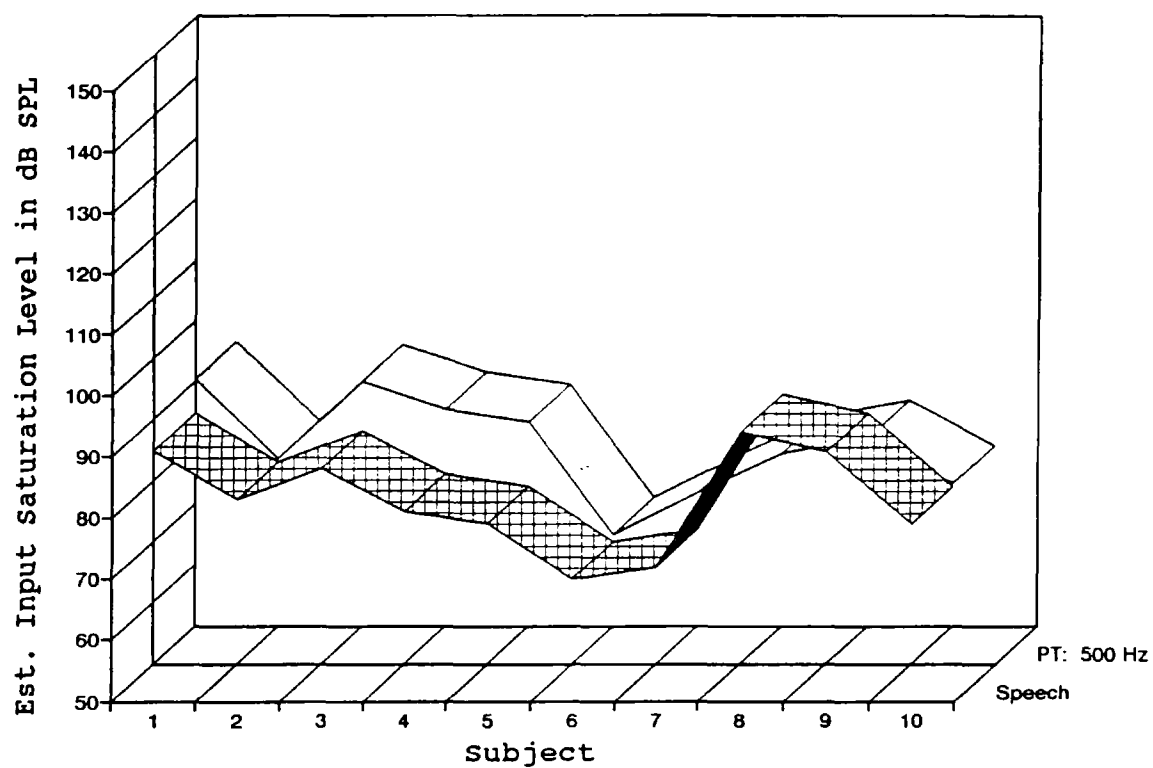


Figure 3. Comparison of the estimated input saturation levels in dB SPL for speech and a 500 Hz pure tone.

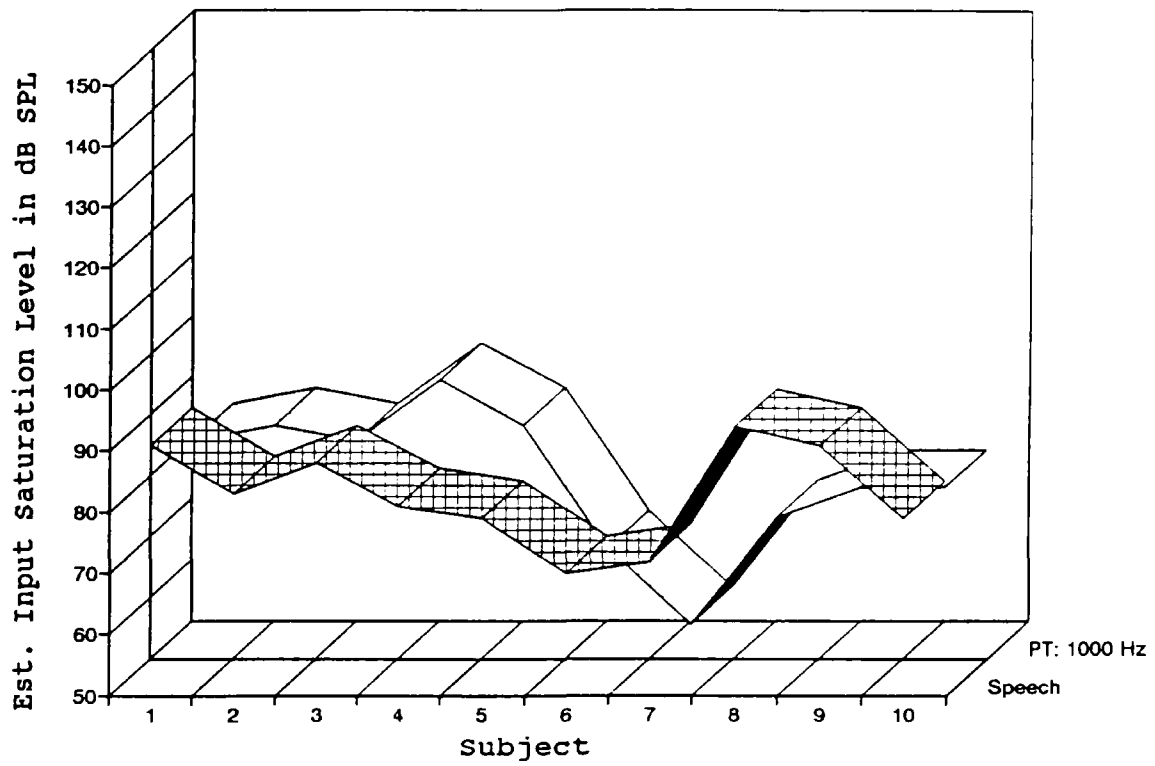


Figure 4. Comparison of the estimated input saturation levels in dB SPL for speech and a 1000 Hz pure tone.

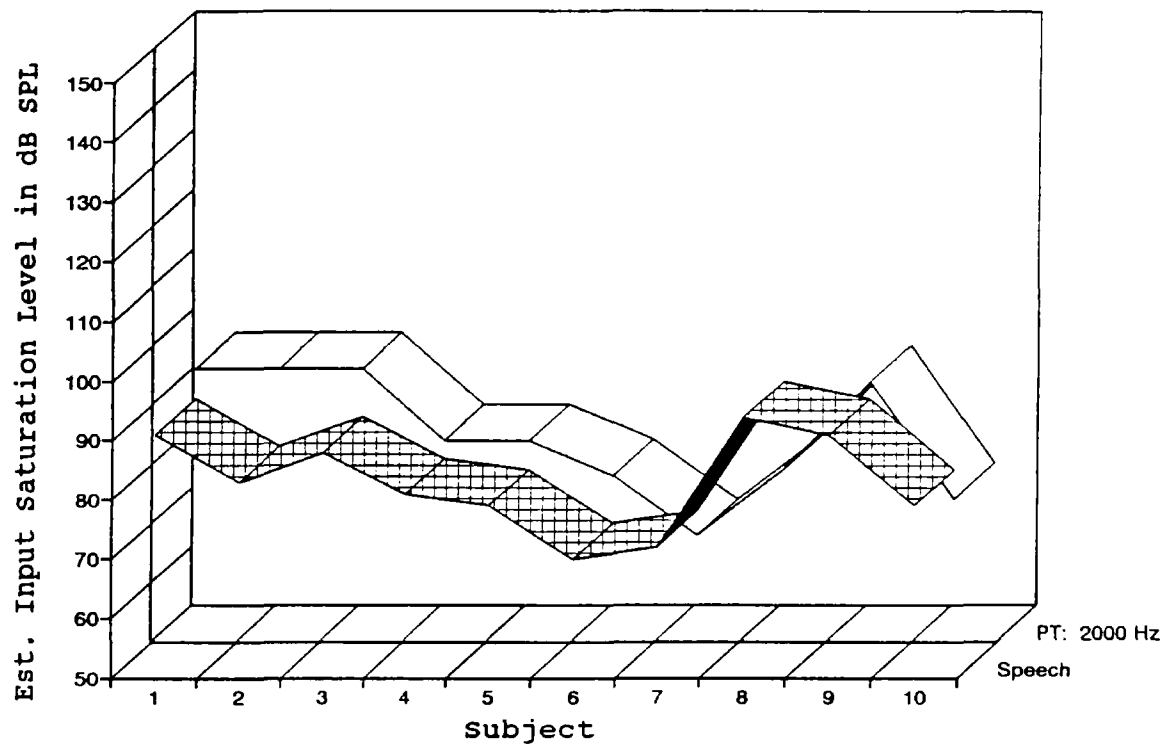


Figure 5. Comparison of the estimated input saturation levels in dB SPL for speech and a 2000 Hz pure tone.

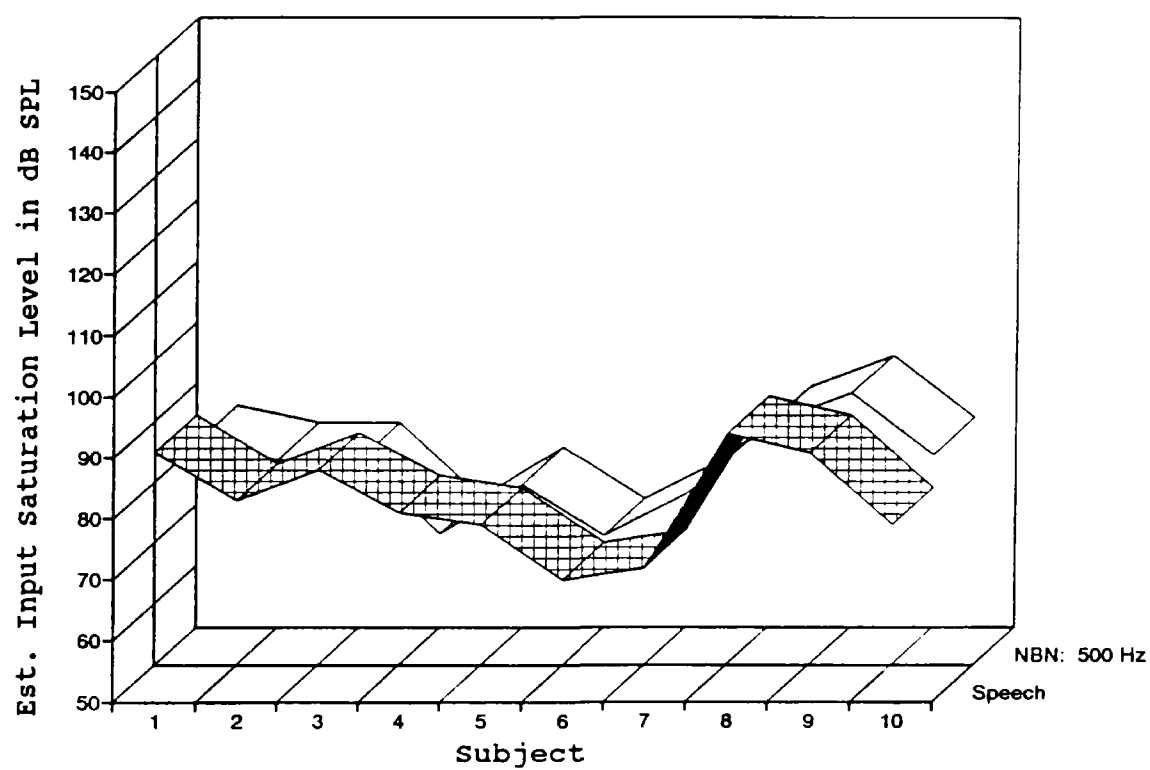


Figure 6. Comparison of the estimated input saturation levels in dB SPL for speech and a band-restricted noise centered at 500 Hz.

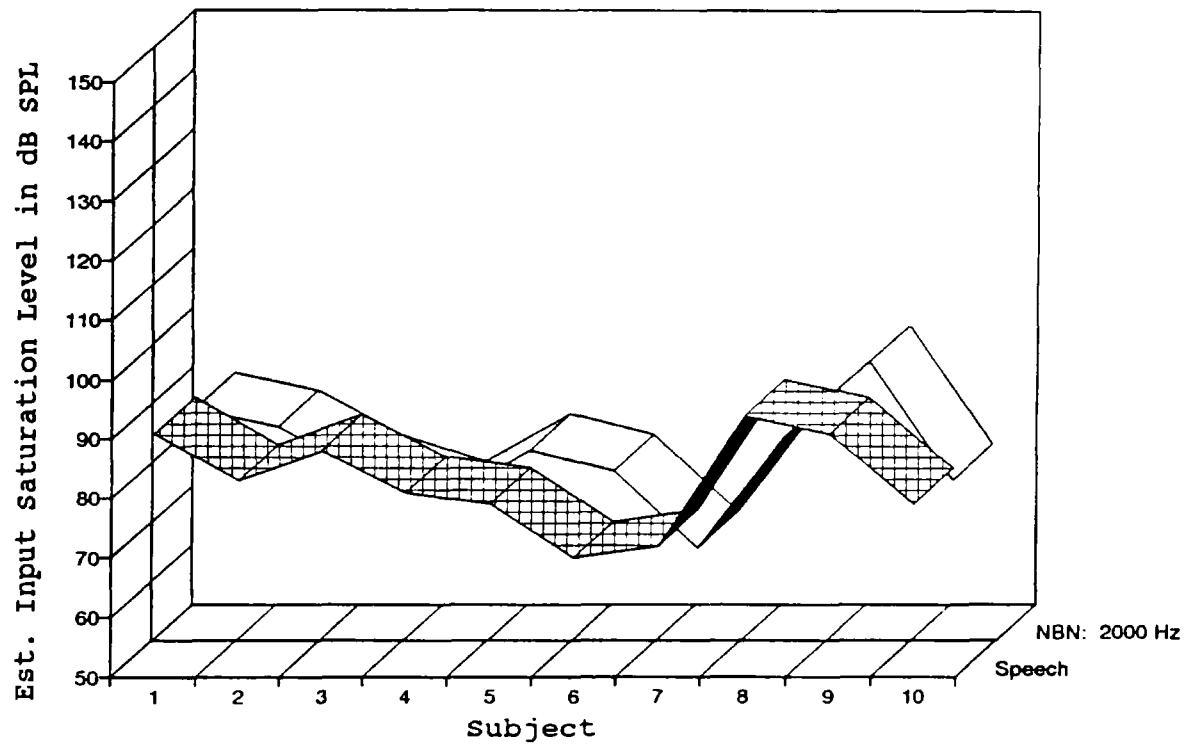


Figure 7. Comparison of the estimated input saturation levels in dB SPL for speech and a band-restricted noise centered at 2000 Hz.

Chapter IV: Discussion

This study investigated the relationship between LDL measurements made with three different stimuli: speech, band-restricted noise, and pure-tones. The results revealed no statistically significant differences between the LDL measurements of the various types of stimuli used in this study. In retrospect, there are several reasons why a significant difference may not have been found. First, this study used a relatively small sample size. The small sample size would restrict the shape of the distributions such that large differences between the data sets must be obtained before a conservative level of significance can be reached. The present study could not demonstrate such large differences between the stimuli used. Second, the variability across and within subjects is high in this type of testing as loudness is very much a subjective phenomena and its measurement may be influenced by numerous extraneous variables such as instructional set and subject bias. For example, even though the same set of instructions was read to each subject, they may have been interpreted differently. Third, Hawkins recently reported that LDLs obtained under standard TDH earphones are problematic and that these measurements may be confounded due simply to the placement of the transducer over the ear (Hawkins & Schum, 1991). Finally, a fairly conservative criteria for significance ($\alpha = .05$) may have been too strict given the sample size.

Still, when the LDL results were applied in the program to selecting the SSPL90 using the Seattle VAMC hearing aid prescriptive strategy, it was found that the use of the frequency-specific stimuli resulted in more "headroom" for many of the

subjects. This is in sharp contrast to the relatively equivalent estimated input saturation levels between the speech stimulus and the band-restricted noise stimuli. Returning to Table 3 on page 12, the input saturation level for subject six using the speech stimulus was 70 dB SPL, whereas it was 78 dB SPL for the 2000 Hz pure tone stimulus. If the SSPL90 of this subject's hearing aid was set by using the speech stimuli then the level at which it can go into saturation is 8 dB lower than if the 2000 Hz pure-tone had been chosen for SSPL90 selection. When the hearing aid is operating in saturation, the wearer will receive a distorted signal and miss out on critical high frequency information. Therefore, by examining LDLs using both speech and 2000 Hz pure tone stimuli, the audiologist may be better equipped to judge which SSPL90 will maximize the hearing aid user's dynamic range before reaching their loudness discomfort level or saturating the output of the hearing aid.

The audiologist also must remain relatively cautious when making hearing aid fitting decisions based on the estimated input saturation levels determined by loudness discomfort level data from different acoustic stimuli. Hawkins recently stated that given the expected measurement error in LDL protocols, the possible truncation of data in the coupler conversions, and the variations between real ear and mean coupler measures, the estimated input saturation level may be, at best, imprecise (Hawkins & Schum, 1991). Schum suggests, that for individuals with moderate sensorineural hearing loss, the hearing aid should provide a smooth maximum output curve that can be reduced to a 2-cc coupler high-frequency average output of at or below a 100 dB SPL. The audiologist can achieve the most efficient results by counseling the hearing

aid user regarding the issue of loudness discomfort, monitoring the user's subjective impressions of the hearing aid fitting during the trial period, and judicious use of output trimmer adjustments.

Several issues remain unanswered regarding the efficacy of LDL measurements in the hearing aid evaluation. What is the face validity of LDLs measurements in hearing aid selection and fitting. What is the consistency and reliability of LDL measurements in hearing aid evaluations. What stimuli should be used to obtain LDL measurements. As output limiting and compression evolve with the application of adaptive circuitry and digital technology, these questions may become paramount.

The results from the current revealed no statistically significant difference between in LDL measurements obtained with spondee words, pure tones, or narrowband noises. The results did show tremendous variability in the LDL measurements both within and between subjects. LDL continues to be a highly subjective measure and regardless of how strict the protocol may be, individual differences may be evident. In addition, a recent article by Filion and Margolis (1992) indicated that large discrepancies exist between LDLs and judgments of loudness discomfort in real-life environments. The current data do suggest, however, that LDLs may prove beneficial for audiologists and that a comparison between the LDLs obtained for speech with those obtained for frequency-specific stimuli may provide the audiologist with information vital to the appropriate selection of the SSPL90 of a hearing aid. The protocols used in this investigation were used to primarily investigate the pre-fitting measurements. Schum and his colleagues at the

University of Iowa, however, have found increased success in their hearing aid fittings by performing LDL measurements after the hearing aid fitting (Hawkins & Schum, 1991). Perhaps a combination of pre- and post-fitting measurements can maximize the success of the hearing aid fitting. Pre-fitting measurements would gather data for speech and frequency-specific stimuli to allow the audiologist to select an appropriate SSPL90 while post-fitting measurements would then use these same stimuli to identify which SSPL90 setting provides the greatest dynamic range for the hearing aid user.

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Appendix A

MCL Instructions

"You will be hearing a group of words, pulsed tones, or noise in one ear. I want you to decide, for each group, which category from the loudness chart in front of you best describes its loudness. I will be looking for your comfortable level. Try to judge each group on its own merit and not on the previous group. The same category may apply more than once."

LDL Instructions

"The test I am about to do now will help me choose a hearing aid for you that will keep sounds from becoming uncomfortably loud. This is important, because if the hearing aid makes sounds too loud you will not want to wear it. However, if it keeps things too soft you won't hear some parts of speech. The levels of loudness are once again shown on the chart. After each group of words, pulsed tones, or noise that you hear, tell me from the chart which loudness level best describes it. Do you have any questions?"

Appendix B

LOUDNESS CHART

PAINFULLY LOUD
EXTREMELY UNCOMFORTABLE
UNCOMFORTABLY LOUD
LOUD, BUT OK
COMFORTABLE, BUT SLIGHTLY LOUD
COMFORTABLE
COMFORTABLE, BUT SLIGHTLY SOFT
SOFT
VERY SOFT

(Hawkins et al, 1987)

Appendix C

Seattle VAMC modifications to the National Acoustics Laboratory-Revised (NAL) hearing aid prescriptive strategy:

- 1) The original NAL formula provided 15 dB of reserve gain across the frequencies. After fitting several hearing aids using this formula, the audiologists believed that this was too much reserve gain, particularly for the in-the-ear hearing aid fittings. Therefore, the 2-cc coupler gain was reduced by 5 dB across all frequencies, bringing the reserve gain down to 10 dB.
- 2) Under the NAL-R prescriptive method, the audiologists believed that they were making compromises in the gain at 2000 Hz (a critical frequency within the speech spectrum) to accommodate the prescribed gain at higher frequencies in the hearing aid fitting. As a result, an additional 10 dB of gain was subtracted from the 2-cc coupler gain measurements for frequencies above 2000 Hz.